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Corn Ear Orientation Effects on Mechanical Damage and Forces on Concave

Ali R. Mahmoud, W. F. Buchele

MEMBER ASAE

THE combine rasp-bar cylinder is the major shelling mechanism of the field harvesting machinery used in the Corn Belt. The cylinder shelling efficiency is excellent when operated at recommended levels of grain moisture and machine settings. Corn buyers and processors, however, claim that grain damage during the shelling process has detrimental effects on the finished products.

Several experimental shellers have been developed at Iowa State University, which shell corn without damaging the grain as much as conventional shellers (Brass 1970, Fox 1969, USDA 1967). Mechanical damage caused by the experimental shellers is less than that caused by the combine cylinder. The ears of corn were fed into these experimental shellers with their axes oriented parallel to the axis of the drums.

The shelling process of the combine cylinder has been studied by viewing high-speed film. The ears of corn were fed into the concave, with the axis of the ear oriented perpendicular to, at an angle to, and parallel to the axis of the cylinder. The literature reviewed revealed no direct information of the effect of initial ear orientation with respect to the threshing cylinder on corn-kernel damage.

Brandini (1969) impact-shelled individual kernels from the cob by a pendulum type impactor. He noted that the direction of applying the force had no significant effect on the magnitude of force required to detach the kernel. Arnold (1967) reported that the sheaf direction and head direction in which wheat was presented to the shelling cylinder had a significant effect on power requirements for threshing. He concluded that feeding of the heads of the wheat sheaf parallel to cylinder axis re-

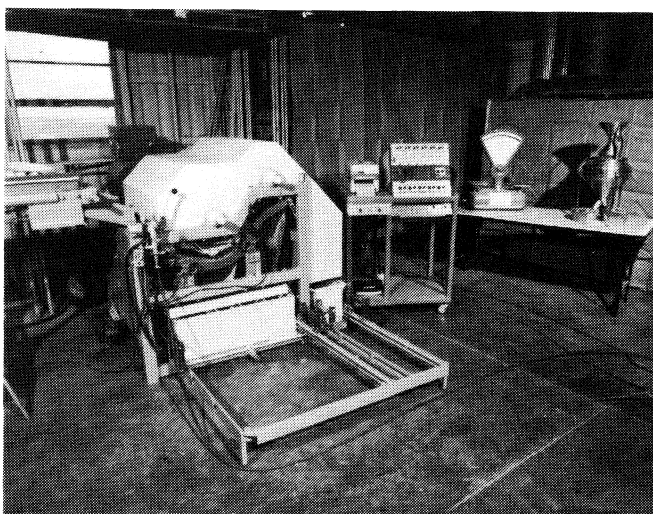


FIG. 1 Shelling laboratory.

quired the least power. Lamp and Buchele (1960) investigated several methods of holding heads of wheat in a centrifugal thresher. They observed that heads extending on radial lines from the center required twice the threshing force of that with reversed mounting. They also noted that holding the heads flat against a retaining cylinder reduced the percentage of threshed grain by 50 percent.

Information on the effect of ear orientation on mechanical damage of corn kernels is needed by the design engineer. Shelling-cylinder designs incorporating this information should have greater shelling efficiency with less kernel damage. Accordingly, the following objectives were formulated:

- 1 To study the effect of ear orientation on kernel damage caused in the shelling process.

- 2 To determine the type and location of the forces acting along the concave.

Experiments were formulated, and equipment and instruments were built to carry out the objectives.

EFFECT OF EAR ORIENTATION ON KERNEL DAMAGE

A stationary laboratory sheller (Fig. 1), constructed from John Deere Model 95 combine parts, was used in this

study. The sheller was fitted with a transparent side to facilitate filming of the shelling process. Ears of DeKalb XL66 variety corn were shelled in the experiment. Ears were selected individually from the field so as to minimize the variations in moisture and weight among the selected ears.

Three initial orientations of ears fed into the combine cylinder were investigated:

- 1 Ear axis perpendicular to cylinder axis (tip-in)
- 2 Ear axis parallel to cylinder axis (roll-in)
- 3 Ear randomly thrown into cylinder (random)

The ears were hand-fed, and three replications were run. A replication consisted of feeding three ears, one at a time, into the cylinder. The shelled corn from the three ears was collected and thoroughly mixed. Random samples for moisture content (oven-dry method, wet basis) and damage evaluation were obtained by Boerner grain divider.

The Fast Green FCF dye method was used for grain-damage evaluation (ref. 7). A kernel was considered damaged if it was broken, cracked, chipped, had bruised pericarp, or any hairline crack in the pericarp. Green dye stained the damaged parts and made the inspection easier. The damaged kernels were

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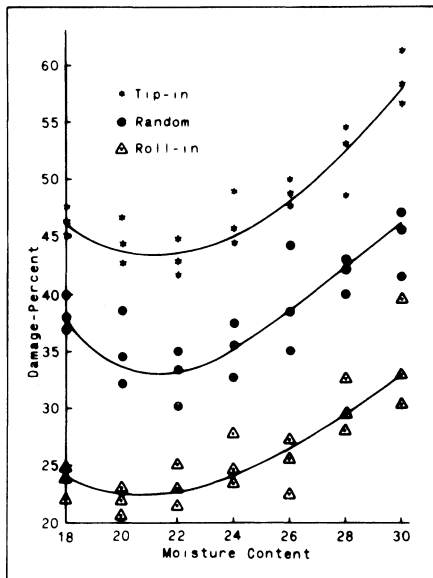


FIG. 2 Effect of method of feeding and moisture content on kernel damage.

weighed and the percentage damage was computed on weight basis for each sample.

RESULTS AND DISCUSSION OF KERNEL DAMAGE

The results of damage at different moisture contents and for the three dif-

ferent orientations are shown in Fig. 2.

The roll-in orientation suffered the least damage at all moisture contents tested, followed by ears fed randomly to the cylinder. The highest damage was suffered by ears fed with their axes perpendicular to the cylinder (tip-in). The minimum damage for all orientations was between 20 and 22 percent moisture content.

The different levels of damage suffered by the different orientations of the ear were partly explained by the following interpretations from a review of a high-speed film for the different orien-

tations:

When the ear was rolled in the path of the rasp-bar of the threshing cylinder, a row of kernels was impacted along the axis of the ear. The radial component of the force drove the impacted kernels and the diametrically opposite row in contact with the concave bar radially into the cob. Some of these kernels (those hit by the teeth of the rasp-bar) were severely damaged on the crown. The inward movement of the kernels and the tangential component of the force caused kernels adjacent to the impacted row to shell. Concurrently, the ear tended to rotate because of the tractive effort of the cylinder and to move down the shelling crescent. The filler

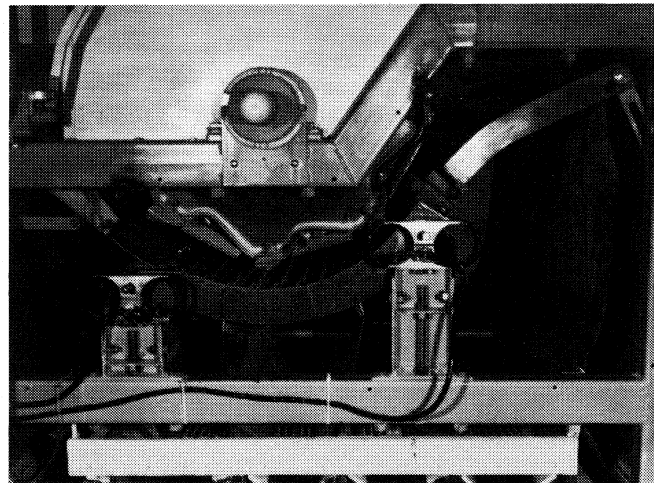


FIG. 3 Concave instrumented with octagonal transducers.

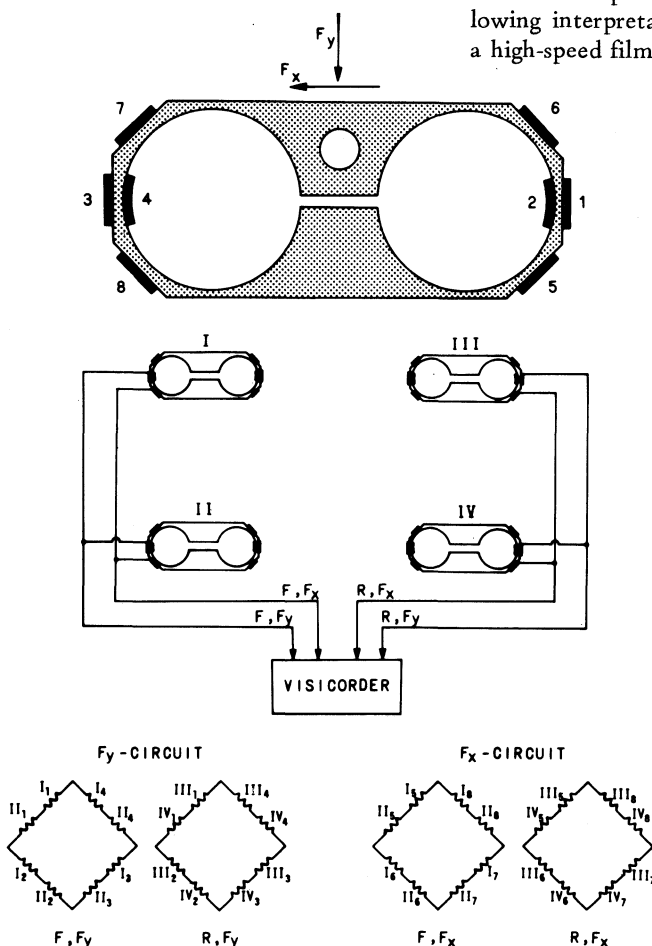


FIG. 4 Schematic diagram of strain gauge octagonal transducers.

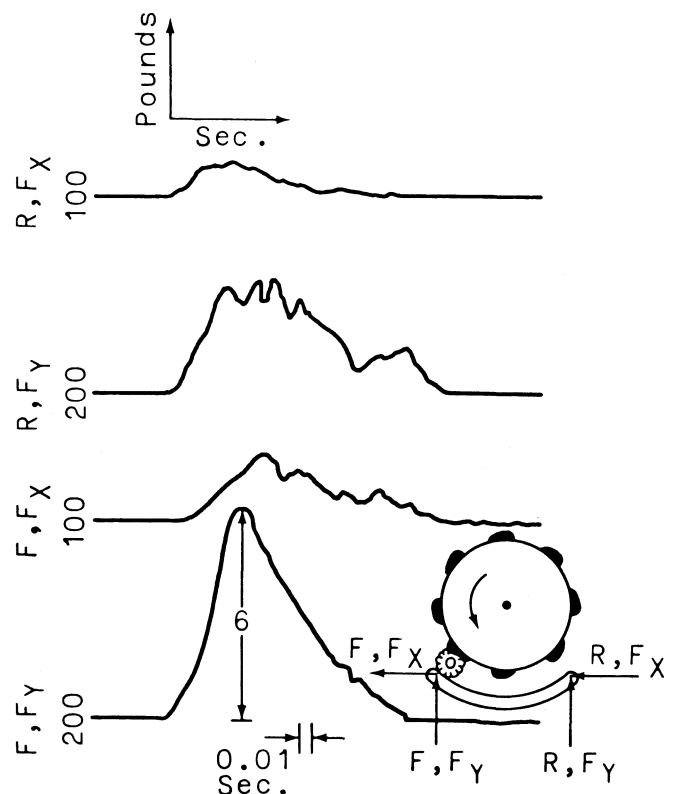


FIG. 5 Reproduction of the roll-in forces versus time.

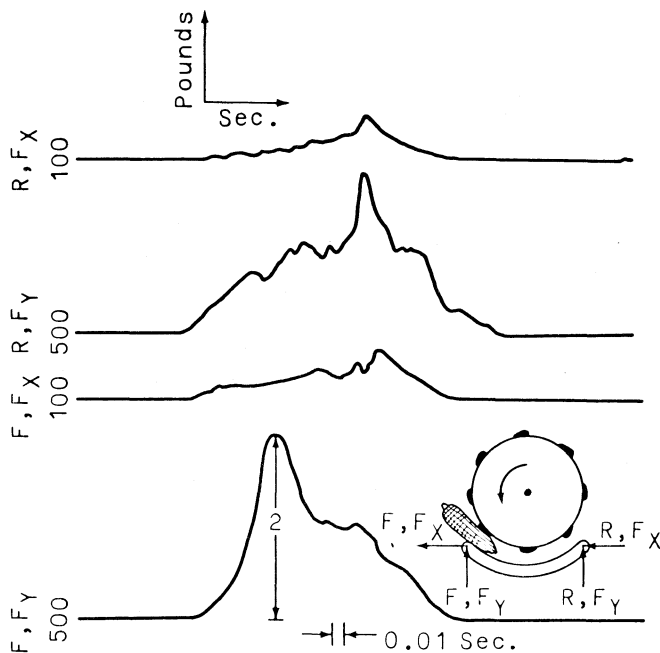


FIG. 6 Reproduction of the tip-in forces versus time.

plate following the rasp-bar imparted additional rotary motion to the ear and caused additional shelling. This sequence of actions was repeated until the cob was swept out of the shelling crescent by the rasp-bar.

Ears fed with their axis perpendicular to the cylinder axis (tip-in) were struck by the rasp-bar at a segment transverse to the ear axis. The impact force acted on a considerably smaller area than with the roll-in orientation. The ear bounced several times against the feeder plate each time it was impacted by a rasp-bar. The tractive effort of the rasp-bar moved the ear down the shelling crescent, and the ear again was hit by the rasp-bar. Continued action on the ear stripped kernels off the cob and moved the ear down the shelling crescent. Some of the kernels lost the upper portion of the crown while still attached to the cob. The successive impacts tended to turn the ear sideways because of angularity of the teeth of the rasp-bar. The ear changed to the roll-in type orientation relatively close to the concave inlet, and it was then acted upon in the manner described for that orientation.

When the ears were randomly thrown in the cylinder, they entered the concave either tip-in, roll-in, or with the axis of the ear at an angle with the axis of the cylinder. In the last instance, the ear changed to the roll-in position sooner than with the tip-in orientation.

The higher level of damage caused by the tip-in orientation could thus be attributed to one or both of the following:

1 The impact forces acted on less area when the ear was fed tip-in than when the ear was fed roll-in.

2 Kernel strength could be higher in one direction than the other.

HIGH-SPEED FILM AND FORCE MEASUREMENTS

Individual ears of DeKalb XL66 at 24-percent moisture content were sorted to be uniform in size. The cylinder was set at 500 rpm, and concave clearance was 1-1/2 in. front and 3/4 in. rear. These clearances were selected in accordance to the ear size chosen for the test.

For each orientation, three ears were fed into the sheller simultaneously as the actuator button was pushed to "on" position. This required good timing on the part of both operators because the film ran through the camera in a matter of 3.5 sec.

The forces recorded by the Visicorder were evaluated from the calibration curves of the transducers. Typical recorded forces for the two orientations are reproduced in Figs. 5 and 6. On these figures, the magnification factor (G) for each force is indicated, as well as the time scale for the chart speed.

The film was reviewed by LW projector (Motion Analyser Model 900B), which allowed study of individual frames and facilitated the tracing of ear advancement in the shelling crescent (Figs. 7 and 8) for the roll-in and tip-in orientations, respectively. The projector was fixed on the top of a drawing board, and the image was projected on a

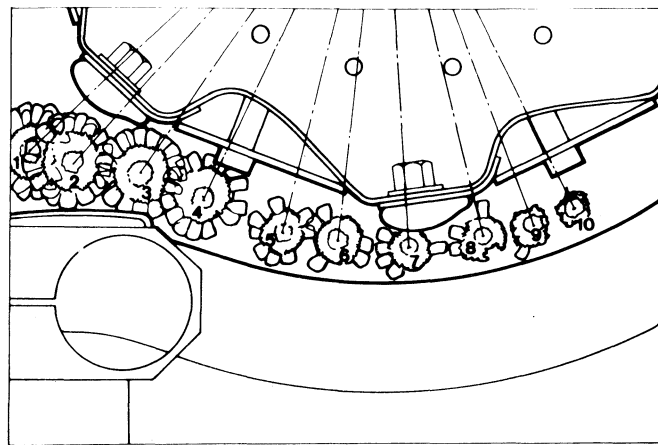


FIG. 7 Traced advance of the ear down the shelling crescent (roll-in).

tracing sheet. The cylinder and concave parts were traced from the first frame, and the film was advanced until the ear entered the concave. This was marked as position 1 (Figs. 7 and 8). The frame counter was set at zero for this position. Successive ear positions were located by advancing the film. Each position was marked on the tracing sheet, and the corresponding number of frames advanced was recorded. The time lapse between one position and the other was determined as:

$$\text{Time (sec)} = \frac{\text{No. of frames advanced}}{\text{Film speed}} \\ = \frac{\text{FM.}}{\text{FM./sec}}$$

The computed time for each position of any one orientation was transposed on the force diagram (Figs. 5 and 6) to determine the corresponding force at the front and rear and for both directions vertical and horizontal (F,Fy; F,Fx; R,Fy; R,Fx). Because some of the ears fed into the cylinder broke and shattered at the start of shelling, only one ear for each orientation was analyzed.

RESULTS AND DISCUSSION OF HIGH-SPEED FILM AND FORCE MEASUREMENT

The angle of wrap (α) (measured from the line connecting the center of the cylinder and concave inlet) was measured for each position marked on the tracing sheet (Figs. 7 and 8). The forces acting in the same direction (vertical or horizontal) at each position of the ear were summed algebraically. The resultant vertical and horizontal forces for each position were resolved graphically to determine the normal (F_N) and tangential (F_T) forces acting on the ear (Fig. 9).

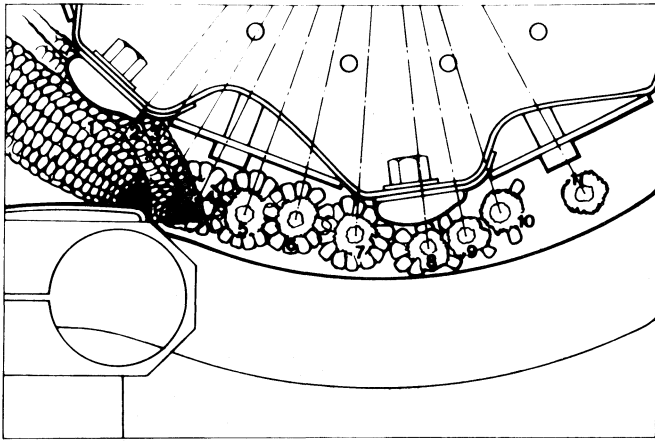


FIG. 8 Traced advance of the ear down the shelling crescent (tip-in).

The normal force (F_N) and the tangential force (F_T) versus the angle of wrap (α) for the roll-in and tip-in orientations are shown, respectively, in Figs. 10 and 11. The extrapolated portions on these figures were computed on the assumption that the rate of advancement of the ear between positions 9 and 10 (Fig. 7) and position 10 and 11 (Fig. 8) were constant for the remainder of the concave length. Accordingly, the normal (F_N) and the tangential (F_T) forces were computed for the full length of concave for the two orientations (Figs. 10 and 11). The extrapolated portions on the figures were the values computed according to the assumption.

When the ear was fed into the cylinder with its axis parallel to the axis of the cylinder (roll-in), the tangential force lagged the normal force (Fig. 10). The maximum normal force (120 lb) occurred at 25 deg from concave inlet. For the first 37 deg along the concave, the normal force was predominant. Beyond this point, the tangential force became predominant and reached a maximum value of 120 lb at 47 deg from concave inlet. The normal force reached the zero

value at 75 deg; the tangential force at 85.

The force distribution for the tip-in orientation shown in Fig. 11, followed the same trend as that of the roll-in orientation. The peak value for the normal force (87 lb), however, was considerably less than the maximum value of the tangential force (115 lb), as well as the peak values of the roll-in orientation (120 lb).

Superimposing the forces for the two orientations illustrates the relative magnitudes of the forces and positions along the concave. The tangential force for the tip-in orientation was slightly higher than that for the roll-in for the first 37 deg of concave (Fig. 12). Beyond that position, the tangential force for the roll-in was considerably higher than that for the tip-in orientation.

The superimposed normal forces (Fig. 13) indicated that, for almost the entire length of concave, the tip-in orientation experiences lower normal forces than the roll-in orientation.

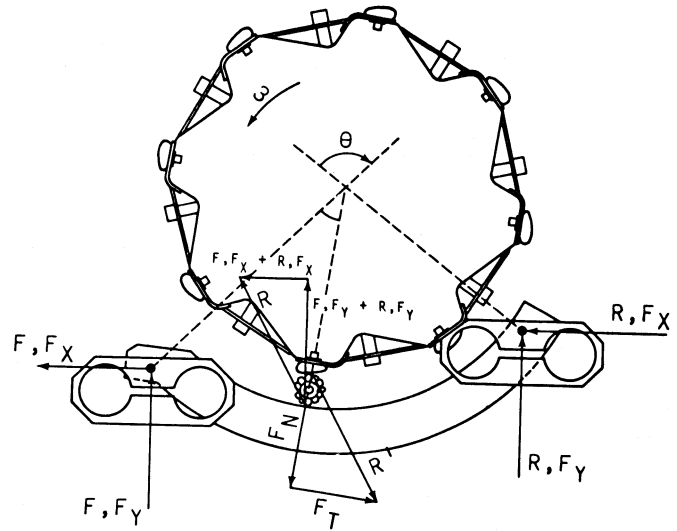


FIG. 9 Graphical resolution of forces acting on the ear.

CONCLUSIONS

Conclusions that would be useful in design modifications to reduce damage can be drawn within the limitations of crop variety and selected ears used in the study of damage and force distribution are as follows:

1 The roll-in feeding orientation produced the least damage for all moisture contents tested, and the tip-in orientation suffered the most damage. Randomly fed ears experienced medium levels of damage. A roll-in orientation mechanism is a feasible addition in the conventional shelling mechanism for damage reduction.

2 Shelling was initiated and continued for about 20 deg from concave inlet by predominantly compressive normal forces and, secondarily, by tangential forces.

3 The normal force for the roll-in oriented ears was slightly higher than

(Continued on page 452)

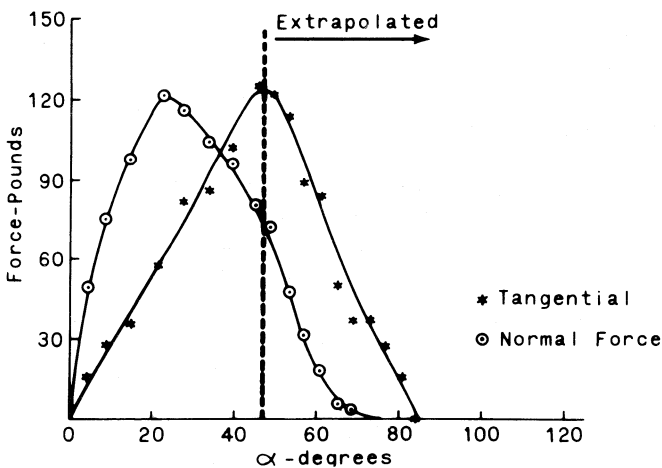


FIG. 10 Tangential and normal forces versus angle of wrap for the roll-in orientation of the ear.

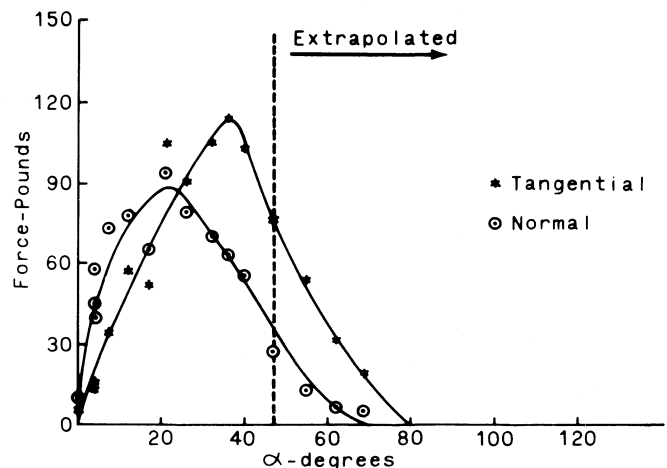


FIG. 11 Tangential and normal forces versus angle of wrap for tip-in orientation of the ear.

Corn Ear Orientation (Continued from page 447)

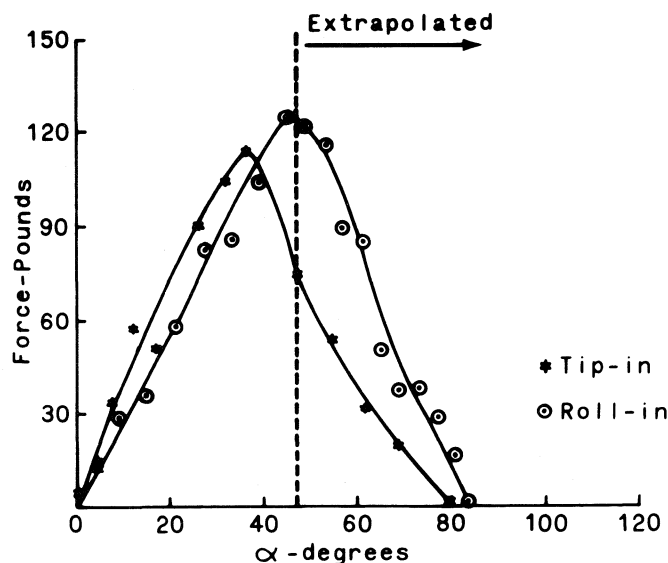


FIG. 12 Tangential forces versus angle of wrap.

that for the tip-in oriented ears along the entire concave length. For the high level of damage sustained by the tip-in orientation, it can be concluded that the area in contact with the rasp-bar for the tip-in orientation must have been much less than that of the roll-in orientation. Thus, the compressive stress on the kernels of the tip-in was greater than on the roll-in orientation ears.

4 The greatest force was experienced in the front portion of the con-

cave. Since shelling becomes much easier after it starts, a conceivable way of reducing damage would be the relief of the partly shelled ears from high-impact forces through a modified configuration of the concave.

References

- 1 Arnold, R. E. 1967. Some aspects of combine design. ASAE Paper No. 67-156, ASAE, St. Joseph, Mich. 49085.
- 2 Brandini, A. 1969. Corn kernel forces during impact shelling. Unpublished M.S. thesis. Library, Iowa State University, Ames Iowa.
- 3 Brass, R. W. 1970. Development of a low damage corn shelling cylinder. Unpublished M.S. thesis. Library, Iowa State University, Ames, Iowa.
- 4 Fox, R. E. 1969. Development of a compression type corn threshing cylinder. Unpublished M.S. thesis. Library, Iowa State University, Ames, Iowa.
- 5 Lamp, B. J., and W. F. Buchele. 1960. Centrifugal threshing of small grain. AGRICULTURAL ENGINEERING 8(1):24-28.
- 6 Mahmoud, A. R. 1972. Distribution of damage in maize combine cylinder and relationship between physico-rheological properties of shelled grain and damage. Unpublished PhD. thesis. Library, Iowa State University, Ames, Iowa.
- 7 USDA. 1967. Hugs and squeezes. Agricultural Research 16(Nov):17.
- 8 USDA. 1967. Hugs and squeezes. Agricultural Research 16(Nov):17.

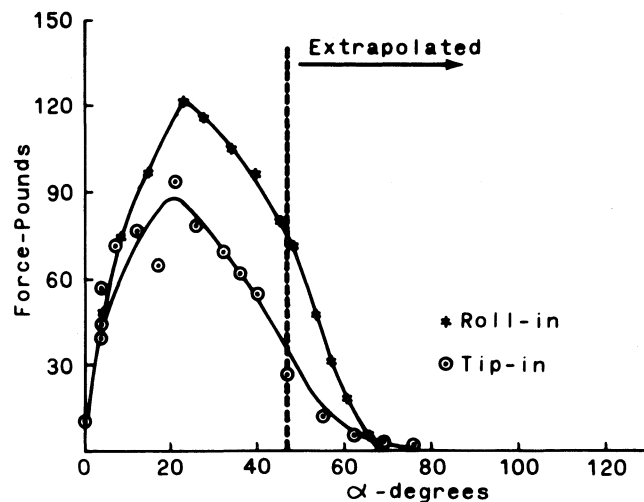


FIG. 13 Normal forces versus angle of wrap.